GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION
SPONSORED PROJECT INITIATION

Date. January 23, 1981

Project Title: Continued Development and Application of Some Neutron and Charged Particle Dosimetry Techniques Utilizing Plastic Track Detectors for Radiotherapy and Health Physics

Project No: E-26-672 (Continuation of E-26-655)

Project Director: Dr. Karl Z. Morgan

Sponsor: Department of Energy; Oak Ridge Operations; Oak Ridge, TN 37830

Agreement Period: From 12/1/80 Until 11/30/81
(R&D Perf and Reporting Periods)

Type Agreement: Contract No. DE-AS05-76EV04814, Modification No. A008

Amount: $44,500

Reports Required: Publication Preprints; Publication Reprints; Progress Report; Final Report

Sponsor Contact Person (s):

Technical Matters

Mr. Robert W. Wood, Director
Pollutant Characterization and Safety
Research Division, EV-34
Mail Stop E-201
Dept. of Energy
Washington, D. C. 20545

Contractual Matters
(thru OCA)

Mr. W. A. Mynatt, Chief
Contract Management Branch
Procurement and Contracts Division
Dept. of Energy
Oak Ridge Operations
P. O. Box E
Oak Ridge, TN 37830

Allen Askew 615/576-0788

FEB 1981
RECEIVED
Research Reports
Office

Defense Priority Rating: None

Assigned to: Nuclear Engineering (School/~~Laboratory~~)

COPIES TO:

Project Director
Division Chief (EES)
School/Laboratory Director
Dean/Director—EES
Accounting Office
Procurement Office
Security Coordinator (OCA)
Reports Coordinator (OCA)
Library, Technical Reports Section
EES Information Office
EES Reports & Procedures
Project File (OCA)
Project Code (GTRI)
Other C. E. Smith

ORGIA INSTITUTE OF TECHNOLOGY OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION/CLOSEOUT SHEET

Date 3/18/85

ject No. E-26-672 School/Lab XXXX NE

ludes Subproject No.(s)

oject Director(s) Dr. Karl Z. Morgan GTRI / XXXX

onsor Department of Energy; Oak Ridge Operations

tle Continued Development and Application of Some Neutron and Charged Particle Dosimetry Techniques Utilizing Plastic Track Detectors for Radiotherapy and Health Physics

ffective Completion Date: 11/30/81 (Performance) (Reports)

Grant/Contract Closeout Actions Remaining:

- [X] None
- [ ] Final Invoice or Final Fiscal Report
- [ ] Closing Documents
- [ ] Final Report of Inventions
- [ ] Govt. Property Inventory & Related Certificate
- [ ] Classified Material Certificate
- [ ] Other

Continues Project No. E-26-655 Continued by Project No. E-26-688

COPIES TO:

Project Director
Research Administrative Network
Research Property Management
Accounting
Procurement/EES Supply Services
Research Security Services
Reports Coordinator (OCA)
Legal Services

Library
GTRI
Research Communications (2)
Project File
Other M. Heyser

A. Jones

OCA 60-1028

E-26-672

SEP 16 1981

2-8887 269

Georgia Institute of Technology

ATLANTA, GEORGIA 30332

OFFICE OF CONTRACT ADMINISTRATION

Telex: 542507 GTRIOCAATL
Fax: (404) 894-3120
Phone: (404) 894- 4814

14 September 1981

U. S. Department of Energy
Pollutant Characterization and Safety
Research Division - Mail Station E-201
Office of Health & Environment Research
Washington, D. C. 20545

Attention: Dr. Robert Wood

Subject: Research Proposal Entitled, "Development and Application of Some Fast Neutron Dosimetry Techniques Utilizing Plastic Track Detectors for Radiotherapy and Health Physics"
Continuation of Contract DE-AS05-76EV04814

Gentlemen:

The GEORGIA INSTITUTE OF TECHNOLOGY desires to submit for your consideration the subject continuation proposal prepared by Dr. John Poston, School of Nuclear Engineering.

We believe you will find the proposal complete; however, if anything additional is desired, please let us know, and we will see that it is forwarded promptly. Any matters pertaining to the scientific program may be referred to Dr. Poston, 404/894-3734. Administrative matters may be referred to the writer, 404/894-4814. In the event of an award it is proposed that either a grant or a cost-reimbursement (no fee) type of contract be used to implement this proposal.

We appreciate the opportunity of submitting this proposal and look forward to continuing work with you on this project.

Very truly yours,

Carol A. Cook
Contracting Officer

lhs
Addressee: Eight (8) copies
Enclosure: Eight (8) copies

cc: Mr. W. A. Mynatt
U. S. Dept. of Energy
Oak Ridge Operations
P. O. Box E
Oak Ridge, Tennessee 37830

Georgia Institute of Technology
A UNIT OF THE UNIVERSITY SYSTEM OF GEORGIA
SCHOOL OF NUCLEAR ENGINEERING AND HEALTH PHYSICS
ATLANTA, GEORGIA 30332
(404) 894-3720

September 9, 1981

Dr. Robert Wood
Pollutant Characterization and Safety
Research Division
Office of Health and Environmental Research
Department of Energy
Washington, D.C. 20545

Dear Dr. Wood:

Attached is the project proposal per your request of 9/1/81 for renewal of contract DE-AS05-76EV04814, "Development and Application of Some Fast Neutron Dosimetry Techniques Utilizing Plastic Track Detectors for Radiotherapy and Health Physics." This renewal is for extension through June, 1982, at which time the final report summarizing the investigations and results of the entire contract period will be submitted.

Sincerely yours,

L. E. Weaver
Director

LEW/lm
Enclosure

U.S. DEPARTMENT OF ENERGY

NOTICE OF ENERGY RD&D PROJECT

FORM DOE 538
(1/78)

APPROVED FOR USE BY
SMITHSONIAN SCIENCE INFORMATION EXCHANGE

FORM APPROVED
OMB NO. 38 R-0190

1. DESCRIPTIVE TITLE OF WORK: Proposal for Renewal of Contract DE-AS05-76EV04814 and to Continue Development and Application of Some Neutron & Charged Particle Dosimetry Techniques Utilizing Plastic Track Detectors for Radiotherapy and Health Physics

2. PERFORMING ORGANIZATION CONTROL NUMBER: E-26-672

3. CONTRACT, GRANT OR PURCHASE ORDER NUMBER: DE-AS05-76EV04814

4. CONTRACTOR'S PRINCIPAL INVESTIGATOR/PROJECT MANAGER AND ADDRESS WHERE WORK IS PERFORMED

a. NAME (Last, First, MI): Poston, John W. PHONE (404) 894-3724

b. BUSINESS ADDRESS: STREET: School of Nuclear Engineering & Health Physics, Georgia Tech
CITY: Atlanta STATE: Georgia ZIP: 30332

5. a. NAME OF PERFORMING ORGANIZATION
Georgia Institute of Technology (Organization) School of Nuclear Engineering & Health Physics (Department)

b. MAILING ADDRESS (If Different From 4B): (Same as above)

c. TYPE OF ORGANIZATION PERFORMING THE WORK (Enter applicable code from instructions): C U

6. SUPPORTING ORGANIZATION

a. DOE PROGRAM DIVISION OR OFFICE (Full Name): Pollutant Characterization and Safety Research Division, EV-34, Office of Health & Environmental Research, Mail Station E-201

b. TECHNICAL MONITOR (Last, First, MI): Wood, Dr. Robert W.

c. ADDRESS (If Different from DOE Hqs): DOE, Washington, DC 20545

d. ADMINISTRATIVE MONITOR (Last, First, MI): Coates, Kaye C.

7. PROJECT SCHEDULE (a) START DATE: 12/1/81 (Month) (Year) (b) EXPECTED COMPLETION DATE: 5/31/82 (Month) (Year)

8. a. FUNDING OPERATING AND CAPITAL EQUIPMENT OBLIGATION (In Thousands of Dollars)

FUNDING ORGANIZATION(S) 12/1/80-11/30/81		APPROXIMATE CUMULATIVE PRIOR FISCAL YEARS	CURRENT FY		
1. DOE	44	218	10		
2.					
3.					

b. DOE BUDGETING AND REPORTING CLASSIFICATION CODE

9. DIRECT SCIENTIFIC AND TECHNICAL MANPOWER

	PROFESSIONAL	GRAD. STUDENTS	OTHER	TOTAL
NUMBER	0	1		1
EQUIVALENT PERSONYEARS	0	0.5		0.5

DETACH HERE BEFORE SUBMITTING

Form ERDA-427
(2575)
ERDAM 3201

U.S. ENERGY RESEARCH & DEVELOPMENT ADMINISTRATION

UNIVERSITY–TYPE CONTRACTOR'S RECOMMENDATION FOR DISPOSITION OF SCIENTIFIC AND TECHNICAL DOCUMENT

(See Instructions on Reverse Side)

1. ERDA REPORT NO.
DE-AS05-76EV04814

2. TITLE
Development and Application of Some Neutron and Charged Particle Dosimetric Techniques Utilizing Plastic Tract Detectors for Radiotherapy and Health Physics

3. TYPE OF DOCUMENT (Check one):

- [x] a. Scientific and technical report
- [ ] b. Conference paper:
  - Title of conference _____
  - Date of conference _____
  - Exact location of conference _____
  - Sponsoring organization _____
- [ ] c. Other (Specify)

4. RECOMMENDED ANNOUNCEMENT AND DISTRIBUTION (Check one):

- [x] a. ERDA's normal announcement and distribution procedures may be followed.
- [ ] b. Make available only within ERDA and to ERDA contractors and other U.S. Government agencies and their contractors.

5. REASON FOR RECOMMENDED RESTRICTIONS:

6. SUBMITTED BY: NAME AND POSITION (Please print or type)

John W. Poston
Associate Professor

Organization

School of Nuclear Engineering and Health Physics
Georgia Institute of Technology
Atlanta, Georgia 30332

Signature	Date
	September 9, 1981

FOR ERDA USE ONLY

7. ERDA CONTRACT ADMINISTRATOR'S COMMENTS, IF ANY, ON ABOVE ANNOUNCEMENT AND DISTRIBUTION RECOMMENDATION:

8. PATENT CLEARANCE:

- [ ] a. ERDA patent clearance has been granted by responsible ERDA patent group.
- [ ] b. Report has been sent to responsible ERDA patent group for clearance
- [ ] c. Patent clearance not required.

PROPOSAL FOR RENEWAL OF CONTRACT DE-AS05-76EV04814 AND TO CONTINUE DEVELOPMENT AND APPLICATION OF SOME NEUTRON AND CHARGED PARTICLE DOSIMETRY TECHNIQUES UTILIZING PLASTIC TRACK DETECTORS FOR RADIOTHERAPY AND HEALTH PHYSICS

BY

Micheal Sanders
School of Nuclear Engineering and Health Physics
Georgia Institute of Technology
Atlanta, Georgia

September, 1981

ABSTRACT

We believe our research into electrochemical etching of polycarbonate foil has provided significant contributions in the measurement of fast neutron, thermal neutron, and alpha particle dose for both physical and biomedical applications. In the coming six months we propose to complete the following studies: (1) development of a simple, nonalbedo, rem-responding damage-track dosimeter for use in the 1 eV to 1 MeV neutron energy range, (2) examination of alternative exchanges, solvents, and pre-treatment methods to improve the etching efficiency and long etching times required when using CR-39 polymer, (3) investigation of the neutron generation found within the human body during high-energy accelerator x-ray radiotherapy treatments and its contribution to the total patient dose, (4) definition of the Georgia Tech Research Reactor (GTRR) epithermal/intermediate energy filtered neutron beam to be used in the Boron Neutron Capture Therapy (BNCT) study, (5) examination of the response of CR-39 and polycarbonate to monoenergetic H, C, and O nuclei and neutrons with energies greater than 20 MeV. The completion of these investigations is expected to help finally provide a simple and reliable dosimeter which is viable, and a preferred choice, for dose measurements of all high LET radiations, especially as applied to the entire neutron energy spectrum. In addition, our studies are helping to allow a clearer understanding of many biomedical and clinical therapy situations in the treatment of malignant cancers.

INTRODUCTION

The complete results to date of our research in the field of electrochemical etching of sensitive polymer foils for the purpose of dosimetry have been accumulated and appear in ORO-4914-5 and our progress reports dated August, 1977, August, 1978, August, 1979, and August, 1980. These reports show the intensive research performed by the investigators in the field as well as some recommendations for the solution of new problems for the advancement of this rapidly expanding and interesting type of dosimetry to many new applications. Some of the recommended studies are already under investigation, and preliminary results have been presented at several scientific meetings including the American Physical Society, Auburn, Alabama, 1975, and Chattanooga, Tennessee, 1979; Health Physics Society, Denver, Colorado, 1976, San Francisco, California, 1976, Atlanta, Georgia, 1977, Minneapolis, Minnesota, 1978, Philadelphia, Pennsylvania, 1979, Seattle, Washington, 1980, and Louisville, Kentucky, 1981; International Radiation Protection Association, Amsterdam, The Netherlands, 1975, and Jerusalem, Israel, 1980; the American Industrial Hygiene Association, Atlanta, Georgia, 1976; and the American Nuclear Society, Raleigh, North Carolina, 1977, and Gainesville, Florida, 1978.

We are currently investigating many of the problems listed under this contract. These include the development a CR-39 rem-responding, damage-track dosimeter usable in the 1 eV to 1 MeV neutron energy range, the improvement of the CR-39 etching time, and the definition of the Boron Neutron Capture Therapy filtered neutron beam. These and other pertinent areas will be thoroughly and actively investigated in the coming six months.

PROPOSED NEW RESEARCH

The field of health physics is constantly searching for improved dosimetry techniques. One area where the need for improvements is becoming increasingly apparent is neutron dose measurement, especially its application to personnel dosimetry, since recent publications suggest the disirability of using a larger value for $(RBE)_n$. The development of electrochemical etching of sensitive polymer foils offers the promise of heretofore unachievable results; for example, an increase in fast neutron dose measurement sensitivity by a factor of 1000 and a chance to get away from the bane of present neutron monitoring, viz. track fading in NTA emulsions. Our studies have led, and will continue to lead, to better understanding of radionuclide distributions and their resultant effects when preferentially absorbed by critical organs of the human body. As our knowledge in this research expands, it has begun to reach out and touch new areas of concern from internal dosimetry and cancer therapy to environmental studies. The following proposal for continued research describes the major questions of current interest in our research into nuclear damage-track dosimetry.

Development of a 1 eV to 1 MeV Neutron Personnel Dosimeter

Unlike polycarbonate, the threshold for neutron-induced damage-track registration in CR-39 is well below 1 MeV and may be somewhat less than 200 keV. Interestingly the dose response of CR-39 to neutrons below 1 MeV seems to be primarily due to recoil protons, much the same as is the case with human tissue. Unfortunately, as the neutron energy falls below 1 MeV the CR-39 dosimetry response exhibits an under-response when compared to the ICRP dose equivalent curve. This under-response becomes increasingly

pronounced as the neutron energy decreases. Our tests have shown that by using a lithium tetraborate charged particle radiator to utilize the $^{10}B(n,\alpha)^{7}Li$ and $^{6}Li(n,\alpha)^{3}H$ reactions, the damage track density and subsequent dosimeter rem-response can be boosted so that it approximately follows the ICRP rem curve in the 100 keV to 1 MeV neutron energy range. We are currently improving this response with thermal neutron shielding and radiator composition tests to hopefully provide a rem-response from approximately 1 eV to 1 MeV. We have also obtained the use of narrow energy band filtered neutron beams at 2 keV, 24 keV, and 144 keV provided by Dr. Robert Schwartz of the NBS Laboratory. These effectively monoenergetic neutron sources will allow us to accurately calibrate the response of our CR-39 neutron dosimeter in this important energy range. When the CR-39 dosimeter capability is added to our previously developed thermal and fast neutron dosimeter using electrochemical etching of polycarbonate foils, a viable, rem-responding dosimeter usable from thermal to 20 MeV neutron energies will be finally realized.

Improvement of the CR-39 Combined Etching Time

Another drawback of the CR-39 polymer foils used in damage-track etching studies is the long (four to ten hours) combined chemical and electronchemical etching times necessary for damage-track amplification. This is due to the highly cross-linked nature of CR-39 which makes it act like a single giant molecule rather than an accumulation of individual coiled linear polymer molecules, as is the case with polycarbonate. This very nature makes it resistant to most common solvents such as C_2H_5OH (used by us to shorten the polycarbonate electrochemical etching time). However, we are currently examining some powerful new surfactants made by DuPont which offer hope in increasing the preferential etch rate along the

latent damage track without much effect on the bulk etching rate along the undamaged surface.

As is well known, the presence of UV radiation and O_2 exposure tends to increase the response of polycarbonate when applied after irradiation but before etching. This is probably due to cleavage of damaged, but unbroken, polymer chains by excitation and free-radical reactions. To date, no information is available on the exact effects of UV radiation and O_2 exposure on CR-39 polymer. We are currently examining the response of neutron irradiated CR-39 with and without post-irradiation UV exposure. We are also looking into the effects of oxidizers, such as H_2O_2, on the post-irradiated CR-39 foils. It is hoped that the incorporation of a simple pre-etch treatment by UV or H_2O_2 will lead to higher sensitivity and shorter etch times for the CR-39 dosimeter.

Tissue Neutron Generation During X-Ray Radiotherapy

The neutron fluence generated by the human body during high-energy x-ray radiotherapy differs significantly from the beam contamination caused by neutron generation in the high Z accelerator components exposed to the primary x-ray beam.

Some of the more important differences are: (1) the neutron energy spectrum dependence on low Z elements in organs of the human body and variation with the x-ray beam energy, (2) in some cases a major portion of the neutron dose is delivered outside the primary treatment area, and (3) this neutron dose is an unavoidable and undesirable aspect of the radiotherapy treatment. Because of this last difference, it is extremely important that the medical physicist know the location and magnitude of the patient dose from this neutron component in order to formulate the optimum therapy plan. Utilizing a heterogeneous human phantom, we are currently

conducting many dose measurements at different depths in the phantom, at all incident angles, both in tissue only and at the bone-tissue interface. These measurements will be taken for several high-energy accelerators in Atlanta hospitals for various field sizes (an important determinant as to whether or not the major neutron dose is deposited within or outside the treatment volume) and simulated tumor locations. The staff at the hospital of Emory University has been especially cooperative in permitting our use of their high voltage therapy machines.

Definition of the GTRR Filtered Epithermal/Intermediate Neutron Beam

Boron Neutron Capture Therapy (BNCT) is an alternative form of cancer therapy used to treat a highly malignant, invasive form of brain cancer called Glioblastoma multiformae. In this therapy mode, a patient is injected with a boron compound highly enriched in ^{10}B. The boronated compound concentrates preferentially in the brain tumor, while the action of the blood brain barrier prevents its entry into the surrounding healthy tissue. The patients head is then irradiated with a beam of thermal neutrons which initiate the $^{10}B(n,\alpha)^{7}Li$ reaction in the boron-loaded brain tumor. The tumor is thus irradiated with high LET alphas and ^{7}Li nuclei whose range is approximately 10 μ, or the diameter of an average cell. Therefore, a very localized, specific reaction takes place whereby the tumor receives a large dose compared to that received by the surrounding healthy tissue. The main problem with this technique is the rapid attenuation of the thermal neutron flux preventing effective treatment of deep-seated tumors. As a possible solution, the substitution of an epithermal beam for the thermal beam has been proposed. We are constructing such an epithermal neutron beam at the Georgia Tech Research Reactor using Al, S, and Ar filtration to remove the fast neutron and gamma

contamination. In order to define and characterize our epithermal beam we are utilizing the unique detection characteristics of our CR-39 neutron dosimetry system. We have already discovered a skewed nature to the neutron beam that was not detected by conventional ionization chamber neutron detection.

Response of CR-39 and Polycarbonate to H, C, O Nuclei and High-Energy Neutrons

With the cooperation of the accelerator facilities at Oak Ridge National Laboratory, we will expose CR-39 and polycarbonate foil samples to monoenergetic C, O, and proton ion beams at several energies to determine exact thresholds for damage-track registration by these particles under different etching conditions. This study should help to determine the dose contribution of each of these recoiled nuclei in CR-39 and polycarbonate. These values can then be compared to those found in human tissue during neutron exposure. We will also investigate the effects of UV and O_2 exposure on the C, O, and H nuclei registration threshold values.

Polycarbonate has been shown to approximately follow the ICRP first collision dose equivalent curve up to about 20 MeV. The increasing use and importance of ultra-high energy accelerators necessitates the development of a neutron dosimeter usable in the neutron energy range greater than 20 MeV. We will investigate the response of our electrochemically etched polycarbonate foil dosimeter and CR-39 to neutrons in this energy range.

DURATION OF THE PROPOSED RESEARCH

The proposed research is intended to be completed within a period of six months which will last from December 1, 1981, to May 31, 1982.

PROPOSED BUDGET

Ph.D. Graduate Research Assistant 1/2 time (Winter and Spring Quarters, 1982)	$6,000
Overhead (55%)	3,300
TOTAL	$9,300